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# Analysis of the paper and wood flow in The Netherlands

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**Abstract**

Current production structures require large amounts of primary materials and are not likely to be sustained without large implications for the environment. A good understanding of societal metabolism is likely to contribute to more sustainable production and consumption. Material flow analysis (MFA) intends to support this understanding by providing insight in material flows. In this article a new method for analyzing materials flows, called STREAMS, is tested. The method is applied to analyze the paper and wood flow through the economic system of The Netherlands. The method is based on data available from the so-called supply and use tables; these tables are made available by Statistics Netherlands and describe the economy of a country in terms of annual supply and use of goods and services by industries and consumers. The method proves to be very useful in analyzing the paper and wood flow in The Netherlands. The method provides detailed information about the final consumption of paper and wood, even for packaging materials and product parts made out of paper and wood. Trends are visible that statistical offices collect less physical data about material flows. This will make the construction of material flow analyses like this one more difficult in the future. 

*Keywords:* Material flow analysis, MFA; Paper flow; Wood flow; Final consumption; End use calculations; Statistical analysis

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## 1. Introduction

Industrial economies are characterized by their massive throughput of materials and energy. Current production structures require large amounts of primary materials which are processed into products, transported, consumed and finally discarded as waste. This way of creating economic growth is not likely to be sustained without large implications for the environment in which production takes place.

A good understanding of societal metabolism is likely to contribute to more sustainable production and consumption. Material flow analysis (MFA) intends to support this understanding by providing insight into the volume, the structure, and the regulating mechanisms of anthropogenic material flows [1].

MFA refers to accounts in physical units (usually in terms of tons) comprising the extraction, production, transformation, consumption, recycling and disposal of materials [2]. Various MFA methods exist which cover approaches such as substance flow analysis, product flow accounts, material balancing and bulk material accounts.

MFA is a fairly new and rapidly growing research field. Accounting of material flows at firm level have been established in many places but similar efforts on the European, national and regional level are still at the beginning.

In Joosten et al. (1999) a new method for analyzing material flows through society is proposed [3]. The method, called STREAMS[1], is based on statistical make and use tables. In the Netherlands these tables are published annually by Statistics Netherlands [4]. The emphasis of the method is at providing detailed information about the final consumption of material flows, especially those material flows that are normally hard to trace like packaging material and product parts. This is valuable information because final consumption data of products and materials are very hard to find. Often, apparent consumption data are used as an estimate of the final consumption. However, this estimate is only reliable for final products that are not processed any further. For materials and intermediate products, apparent consumption rather means 'the use in industry' which is not a very good estimate for final consumption. Especially for open economies, the difference between imports and exports of materials and products made out of these materials influence the reliability using apparent consumption data as final consumption data.

In Joosten et al. (1998) the STREAMS method is tested successfully on the plastic flows in The Netherlands [5]. The aim of this study is to test the method on the paper and wood flows and providing insights in the paper and wood flows in The Netherlands. We will also refine the method where necessary. We have chosen for analyzing the paper and wood flow because it is an important material flow in The Netherlands in terms of weight and the final consumption is widely spread over many final consumers. Moreover, the STREAMS method is very suitable for tracing packaging materials through the economy and paper products are used in large quantities for packaging purposes [6].

[1] STREAMS is an acronym for STatistical REsearch for Analysing Material Streams.

The analysis described here is executed for the reference year 1990. This reference year was chosen since it enabled us to make use of the work of Blauwendraat and van Dalen as a starting point [7]. Furthermore, after 1990 the amount of physical data collected by Statistics Netherlands declined.

In Section 2 we will describe the method shortly and propose some refinements. In Section 3 the results of the analysis are described which results in a discussion about the method and results in Section 4. We will end with conclusions and recommendations.

## 2. The STREAMS method

The STREAMS-method makes use of the supply and use tables of The Netherlands, published by Statistics Netherlands [4]. The supply and use tables give an integral view of the material flows (expressed in monetary units) in the economy in which in principle every product, producer and consumer are taken into account.[2] These tables show the annual supply and use of goods and services by industries in monetary terms [in million Dfl.[3] (1990)]. They have the form as shown in Fig. 1. The supply table gives the production value of about 800 commodity groups produced by 250 industries. The imports of the goods and services are also given. The use table presents the purchases of commodities by industries, final demand categories for those commodities (e.g. exports, consumption by households and government) and the value added of the industries [8]. In the supply and use tables of The Netherlands 37 paper products and 26 wood products are discerned.

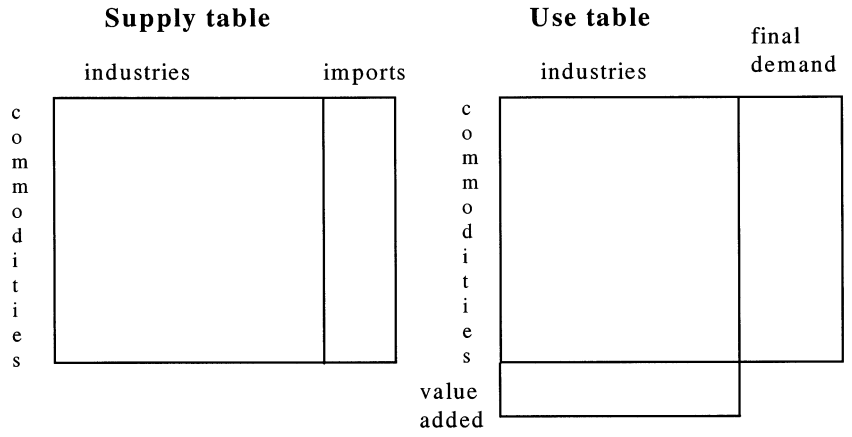


Fig. 1. Schematic representation of supply and use tables as published by Statistics Netherlands [8].

[2] Only the products that are sold onto the market are recorded in the statistics, so it excludes non-traded products.

[3] 1 Dutch Guilder (Dfl.) is approximately 0.5 U.S.$ (1990).

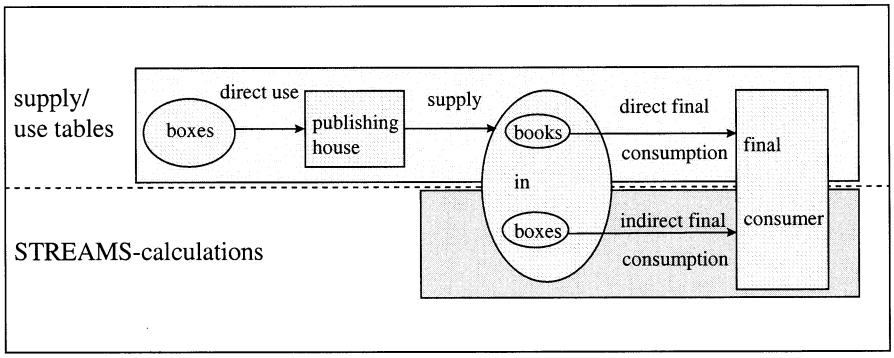


Fig. 2. Schematic relationship between supply and use tables and further calculations.

To analyze the physical flows of paper and wood products through the Dutch economy we need to convert the monetary supply and use data for paper and wood products to physical terms (i.e. kilotons). Joosten et al. (1998) have done this for plastics by dividing all rows by the mean export prices of the plastic products [5]. For paper products the conversion to physical data has been done by Statistics Netherlands [8]. These data are available on an aggregated level [7]. We disaggregate these data by assuming uniform prices within industrial categories. We will use the method of Statistics Netherlands instead of the approach used by Joosten et al. (1999) [3] to obtain physical data. This will be described in Section 2.1.

At this stage in the analysis a physical supply and use table for paper and wood products is available which tells us how much paper and wood is produced, consumed, imported and exported and by whom. However, all use-data are only related to direct purchases of paper and wood products. Many types of paper and wood products are used as packaging material and some wood products are widely used as components in the manufacturing of commodities. This means that the physical supply and use tables do not yet give any information about the final destination of these paper and wood products but only about the direct use. For products that are not regarded as packaging material or product parts, the supply and use tables give the final destination and therefore the final consumption. In order to calculate the final consumption of packaging products and product parts we need to do further calculations.

The relation between the physical supply and use tables and further calculations is shown in Fig. 2. In Fig. 2 cardboard boxes and books are taken as an example. It shows that the physical supply and use tables state the amount of boxes that are purchased directly by a publishing house (direct use). This industry produces books which are packed in the cardboard boxes. The supply and use tables also show the amount of books purchased by libraries (direct final consumption). Further calculations result in insights in the amount of boxes and the amount of packaging material that actually end-up at the final consumers (indirect final consumption).

Calculation of the indirect final consumption is a complicated process. Starting with the physical supply and use tables a lot of matrix multiplication has to be carried out, different cross-cuttings of tables have to be used as starting point for other calculations etc. We will now describe the method as used for the analysis of the indirect final consumption of paper and wood products shortly but refer to Joosten et al. (1999) [3] for a detailed description of the general method.

For all paper and wood products in the supply and use tables it is estimated whether they are used as packaging material, product component or as final product. The paper and wood products that are applied as packaging material or product component are listed in Table 1 and are used in further calculations. For all 800 commodities in the supply and use tables we determine if these paper and wood products are used in the manufacturing process. This is possible because the use table states which industries purchase the paper and wood products and the supply table states the output of these industries. We allocated the amount of paper and wood products that are purchased by the industries over the output of the industries.[4] At this stage all commodities that are manufactured by the industries have a packaging or component share expressed in kilogram paper or wood product per million guilder commodity output.

The average packaging or component share of all commodities is calculated, also in kg paper or wood product per million guilder of commodity output. This is necessary because different industries may produce the same products but use different packaging technologies.

Table 1
Paper and wood products that are likely to be consumed indirectly[a]

| Paper product type | Paper products | Wood product type | Wood product |
|---|---|---|---|
| Packaging | Packaging paper<br>Packaging print | Pallets | Pallets |
| | Paper packaging products | Other packaging | Crates |
| | Corrugated card board<br>Packaging board | | Other packaging products |
| | Other card board | Semi-finished product | Sawnwood<br>Plywood<br>Particle wood<br>Intermediate wood products |

[a] As packaging material and product part.

[4] Some industries however manufacture several commodities of which some are likely to be packed with paper or wood products or contain wooden components and others are not. Joosten et al. (1998) did not distinguish between these commodities and assigned the same packaging or component share to all commodities produced by an industry. In our analysis we will make this distinction by making by estimating for all 800 commodities if they are likely to be packed or not or if they are likely to contain wooden products components. This analysis makes it possible that some commodities are packed and others are not while they are all produced by the same industry.

We use the packaging and component shares to determine where the packaging material and the components end up. The use table states the amount (in million guilders) of commodities that are purchased annually by the industries and final demand categories. By multiplying all these purchases with the packaging or component shares of the commodities we allocate the packaging material and product components over the final consumers of the commodities.

Combining these results with the physical supply and use tables, which present the direct use of paper and wood products, both the direct and indirect final consumption of paper and wood products are calculated.

### 2.1. Price calculations

We have stated a short description of the methodology to calculate the direct and indirect final consumption of paper and wood products. An important step in the calculations is the conversion of the monetary make and use data for paper and wood products into physical terms. This conversion is difficult because a large variety in quality exists for paper and wood products which has a direct effect on the prices. Statistics Netherlands has developed a method for conversion of monetary data into physical data that we use in the conversion process of the wood product data [8].

Before doing so, we separate the rows containing the wood data from the original supply and use tables. This results in a use table and a make table containing 26 rows (wood products) and 250 columns (industries). We will call these make and use tables together: the balance. All the numbers in the balance that represent the amount of wood products that are purchased and produced by the industries (in million guilders) we call items.

For every item in the balance prices are collected. Import and export prices are derived from the foreign trade statistics. In some cases production statistics provided data on produced or used quantities. Sometimes this information covers the whole industry while in other cases it only refers to part of the industry, mainly large firms. In the latter case it is assumed that the derived price is representative for the whole industry. In most cases, however, direct data on product prices are not available and have to be derived in an indirect way. In this case export prices from the foreign trade statistics are used for the conversion of monetary domestic production data while import prices are assumed to be representative for the domestic consumption prices.

After conversion from monetary terms to physical terms for each item in the balance, the tables are tested. First, it is analyzed whether the total supply of one product is equal to the total consumption of that product using the following equation [8]:

$$\sum P_i + I = \sum C_i + E + \sum C_{h,g} + \Delta \text{ stocks} \quad (1)$$

where: $\Sigma P_i$, total production of wood product by industries; $I$, import of wood product; $\Sigma C_i$, total consumption by industries of wood product; $E$, export of wood

product; $\Sigma C_{h,g}$, total consumption by households and government of wood product; $\Delta$ stocks, changes in stocks of wood product.

Inconsistencies are removed by solving the equation for all wood products, where items for which no direct information is available are adjusted using other sources which contain direct physical information on production or consumption of wood products [9,10].

Secondly, it is analyzed whether the total output of an industry in physical terms is equal to the total input in physical terms [8]. So for the production of wood products Eq. (2) holds:

$$\sum P_w = \sum C_w + \sum C_o - \sum W_{w,o} \tag{2}$$

where: $\Sigma P_w$, total production of wood products per industry; $\Sigma C_w$, total consumption of wood and intermediate wood products per industry; $\Sigma C_o$, total consumption of other materials per industry; $\Sigma W_{w,o}$, total amount of waste of wood and the other materials, generated per industry.

This equation provides an instrument for testing the reliability of the estimated output of an industry. By doing so the price estimates that seems the least reliable are adapted by using other data sources [9,10]. The adaptations influence Eq. (1) and therefore the testing process has to start all over. After many iterations both equations hold and the physical supply and use tables are ready.

## 3. The paper and wood flows in The Netherlands

For every paper and wood product that is analyzed, the STREAMS-analysis results in a table that presents the indirect final consumption by industries, service industries and other final consumers. The tables have the same shape as the original use tables: 800 commodities by 250 industries. Different types of information can be read from the tables. The direct final consumption follows directly from the physical make and use tables. The results of the analysis are presented in a very aggregated way in Tables 2–8.

Table 2 shows the direct and indirect (packaging) final consumption of the paper products. We categorized the 36 paper products into six categories, which will be used in later tables. The table shows that more than a third (1250 kt) of the paper used in the Netherlands (3550 kt) in 1990 is used as packaging material. Corrugated board is used mostly for packaging purposes (600 kt). Other large product categories are newspapers (350 kt), advertisement printing (350 kt), magazines (200 kt) and hygienic paper (200 kt).[5]

In Table 3 the direct and indirect final consumption (packaging and product components) of wood products is presented. The 26 wood products are also categorized into six categories. The table shows that the amount of packaging wood

[5] We present rounded numbers because the uncertainties in the calculations do not justify a higher accuracy . In the tables we do present the exact outcomes of the calculations.

Table 2
Direct and indirect final consumption of paper products as calculated for The Netherlands in 1990 (kt)

| Paper products | Direct | As packaging material | Total |
|---|---|---|---|
| *Basic paper types* | 319 | 0 | 319 |
| Pulp | 41 | 0 | 41 |
| Recovered paper | 25 | 0 | 25 |
| Basic paper | 94 | 0 | 94 |
| Graphical paper and board | 130 | 0 | 130 |
| Special paper | 23 | 0 | 23 |
| Other paper products | 6 | 0 | 6 |
| *Office paper* | 269 | 0 | 269 |
| Paper rolls and graph. Paper | 48 | 0 | 48 |
| Envelopes | 72 | 0 | 72 |
| Correspondence paper | 11 | 0 | 11 |
| Chain forms | 79 | 0 | 79 |
| Labels | 59 | 0 | 59 |
| *Books* | 141 | 0 | 141 |
| Books | 1 | 0 | 1 |
| Schoolbooks | 31 | 0 | 31 |
| Encyclopedias | 25 | 0 | 25 |
| Other books | 28 | 0 | 28 |
| Bind products | 57 | 0 | 57 |
| *Magazines* | 648 | 0 | 648 |
| Magazines | 150 | 0 | 206 |
| Newspapers | 341 | 0 | 341 |
| Television magazines | 38 | 0 | 38 |
| Professional magazines | 49 | 0 | 49 |
| Other magazines | 14 | 0 | 14 |
| *Other categories* | 777 | 0 | 777 |
| Hygienic paper | 188 | 0 | 188 |
| Cartographic print | 3 | 0 | 3 |
| Cigarette paper | 9 | 0 | 9 |
| Securities, money | 102 | 0 | 102 |
| Wall paper | 15 | 0 | 15 |
| Postcards | 2 | 0 | 2 |
| Calendars | 9 | 0 | 9 |
| Advertisement printing | 340 | 0 | 340 |
| Flyers | 109 | 0 | 109 |
| *Paper packaging* | 140 | 1254 | 1394 |
| Paper packaging products | 14 | 122 | 136 |
| Corrugated board | 31 | 584 | 615 |
| Packaging card board | 20 | 368 | 388 |
| Other card board | 51 | 13 | 64 |
| Packaging paper | 23 | 80 | 103 |
| Packaging print | 1 | 87 | 88 |
| Total | 2294 | 1255 | 3548 |

and wooden components used in the Netherlands is relatively small compared to the direct final consumption.

Tables 4 and 5 show the foreign trade of paper and wood products. It is shown that 750 kt paper products and 650 kt wood products are imported indirectly as part of (other) commodities (21 and 17%, respectively of the total final consumption).

Table 3
Direct and indirect final consumption of wood products as calculated for The Netherlands in 1990 (kt)

| Wood products | Direct | Indirect as product components | Indirect as packaging | Total |
|---|---|---|---|---|
| *Basic wood* | 1093 | 103 | 0 | 1196 |
| Wood | 347 | 0 | 0 | 347 |
| Sawnwood etc. | 746 | 103 | 0 | 849 |
| *Board* | 574 | 114 | 0 | 688 |
| Board (no veneer) | 283 | 43 | 0 | 325 |
| Plywood | 205 | 72 | 0 | 277 |
| Other board | 86 | 0 | 0 | 86 |
| *Interior* | 875 | 18 | 0 | 893 |
| Stairs | 33 | 0 | 0 | 33 |
| Closet, cupboard etc. | 23 | 0 | 0 | 23 |
| Kitchen elements | 67 | 0 | 0 | 67 |
| Other carpentry | 39 | 0 | 0 | 39 |
| Furniture parts | 67 | 18 | 0 | 85 |
| Parquet | 35 | 0 | 0 | 35 |
| Wood based beds | 31 | 0 | 0 | 31 |
| Special furniture | 135 | 0 | 0 | 135 |
| Furniture | 410 | 0 | 0 | 410 |
| Furniture buildings | 33 | 0 | 0 | 33 |
| *Building* | 376 | 0 | 0 | 376 |
| Doors | 118 | 0 | 0 | 118 |
| Window-frames | 95 | 0 | 0 | 95 |
| Assembly constructions | 157 | 0 | 0 | 157 |
| Scaffoldings | 7 | 0 | 0 | 7 |
| *Packaging* | 122 | 0 | 427 | 549 |
| Other packaging wood | 15 | 0 | 92 | 107 |
| Crates | 29 | 0 | 124 | 153 |
| Pallets | 78 | 0 | 212 | 289 |
| *Other products* | 155 | 105 | 0 | 260 |
| Coffins | 18 | 0 | 0 | 18 |
| Other final wood products | 7 | 0 | 0 | 7 |
| Other intermediates | 113 | 105 | 0 | 218 |
| Brush products | 17 | 0 | 0 | 17 |
| Total | 3194 | 340 | 427 | 3961 |

Table 4
Foreign trade of paper products by The Netherlands in 1990 (kt)

| Paper products | Export direct | Export indirect | Import direct | Import indirect |
|---|---|---|---|---|
| Basic paper types | 2395 | 0 | 3291 | 0 |
| Office paper | 55 | 0 | 108 | 0 |
| Books | 72 | 0 | 70 | 0 |
| Magazines | 42 | 0 | 23 | 0 |
| Other categories | 240 | 0 | 228 | 0 |
| Paper packaging | 586 | 600 | 1062 | 741 |
| Total | 3390 | 600 | 4782 | 741 |

Table 5
Foreign trade of wood products by The Netherlands in 1990 (kt)

| Wood products | Export direct | Export indirect | Import direct | Import indirect |
|---|---|---|---|---|
| Wood | 873 | 40 | 2644 | 77 |
| Board | 76 | 45 | 1339 | 96 |
| Interior products | 181 | 5 | 414 | 11 |
| Building products | 53 | 0 | 37 | 0 |
| Packaging products | 96 | 260 | 72 | 327 |
| Other products | 58 | 34 | 61 | 106 |
| Total | 1337 | 384 | 4568 | 617 |

Table 6
Final consumption of paper products as calculated for The Netherlands in 1990, by final demand category (kt)

| | Direct | As packaging | Total |
|---|---|---|---|
| Agriculture and fishing | 3 | 22 | 26 |
| Industry | 307 | 290 | 597 |
| Buildings | 23 | 46 | 69 |
| Trade | 377 | 25 | 402 |
| Other services | 743 | 132 | 875 |
| Households | 744 | 681 | 1425 |
| Investments | 1 | 46 | 46 |
| Stock increase | 61 | 12 | 73 |
| Other categories | 33 | 2 | 35 |
| Total | 2294 | 1255 | 3548 |

Table 6 shows the final consumption of paper products by different consumer categories. To create this table the 300 industries and other demand categories in the make and use tables are aggregated into nine categories. Households are the major consumers (1450 kt). A considerable part of this is the indirect consumption

of packaging material (700 kt or 48%). Table 7 shows the final consumption in The Netherlands of wood products by different categories of consumers. Here the households are also the major consumers (1400 kt wood products or 39%) followed by construction industries (850 kt or 24%).

Table 8 shows for which category of commodities the paper and wood products are used. It shows the amount of wood and paper products that are 'attached' to or incorporated in the commodities, as packaging material or product component. To create this table the 800 commodities in the make and use tables are aggregated into nine categories.

Table 7
Final consumption of wood products as calculated for The Netherlands in 1990 by final demand category (kt)

| Categories | Direct | Indirect as packaging | Indirect as product component | Total |
|---|---|---|---|---|
| Agriculture and fishing | 34 | 5 | 0 | 39 |
| Industry | 154 | 198 | 18 | 371 |
| Buildings | 913 | 39 | 0 | 953 |
| Trade | 48 | 12 | 0 | 60 |
| Other services | 199 | 46 | 10 | 255 |
| Households | 1230 | 95 | 219 | 1544 |
| Investments | 415 | 25 | 89 | 529 |
| Stock increase | −13 | 7 | 4 | −3 |
| Other categories | 159 | 0 | 0 | 160 |
| Total | 3140 | 427 | 340 | 3908 |

Table 8
Indirect final paper and wood consumption as calculated for The Netherlands in 1990 by commodity categories (kt)

| Commodity categories | Packaging wood products | Wooden components | Packaging paper products | Total indirect consumption |
|---|---|---|---|---|
| Food and tobacco products | 103 | 0 | 556 | 660 |
| Textiles and fashion articles | 3 | 7 | 102 | 112 |
| Paper and printing products | 31 | 0 | 33 | 64 |
| Construction materials and interior | 32 | 81 | 75 | 188 |
| Chemical products | 70 | 0 | 162 | 232 |
| Metal products and machinery | 105 | 32 | 128 | 265 |
| Transportation | 20 | 0 | 12 | 33 |
| Other products | 63 | 219 | 201 | 484 |
| Total | 428 | 340 | 1269 | 2037 |

Table 9
Purchases and production of basic paper and wood products by the paper and wood industries in The Netherlands in 1990 (kt)

| | Purchases | Production |
|---|---|---|
| Wood | 679 | 650 |
| Sawnwood | 2067 | 361 |
| Board (no veneer) | 476 | 78 |
| Plywood | 411 | 66 |
| Other board | 582 | 61 |
| Total | 4215 | 1217 |

In Tables 2–8 the final consumption of paper and wood products in The Netherlands is stated. To do so the paper and wood purchases of the paper and wood industries have been eliminated in order to prevent double counting.[6] Table 9 presents the purchases and the production of paper and wood products of the paper and wood industries.

Tables 2–9 are used to construct a flow chart (Fig. 3) of the paper and wood products through the economy of The Netherlands in 1990. The figure shows the paper and wood flow in the Dutch economy from primary production to waste processing. To keep the picture readable all wood and paper products have been aggregated to one wood and one paper stream, respectively. Fig. 3 is not a mass-balance. It shows the kilotonnes of paper and wood products instead of solely the kilotonnes of paper and wood. Besides recovered paper no waste streams have been depicted because the supply and use tables do not give any information about these streams. The same holds for the production of wood pulp for the paper industry. Fig. 3 demonstrates the open character of the Dutch economy (large import and export flows in all steps of the life cycle), especially for primary materials. Furthermore it shows that most paper and wood resources are imported (pulp and wood).

## 4. Discussion

### *4.1. Methodological aspects*

In this chapter we will focus on the shortcomings of the STREAMS method and the ways that they influence the results. Furthermore we will discuss aspects in the calculations that affect the reliability of the results.

[6] If the purchases of the paper and wood industries would not have been set to zero the following situation would have occurred: both wood based panels purchased by the furniture manufacturing industries and the furniture that contain these panels would have been counted in the total consumption. The wood based panels would have been counted twice.

The first shortcoming of the method is that the supply and use tables that are used as starting point for the material flow analysis present transactions only when they have economic value. This might create problems when analyzing the material flow. Waste streams for example are not stated in these tables. In order to get a

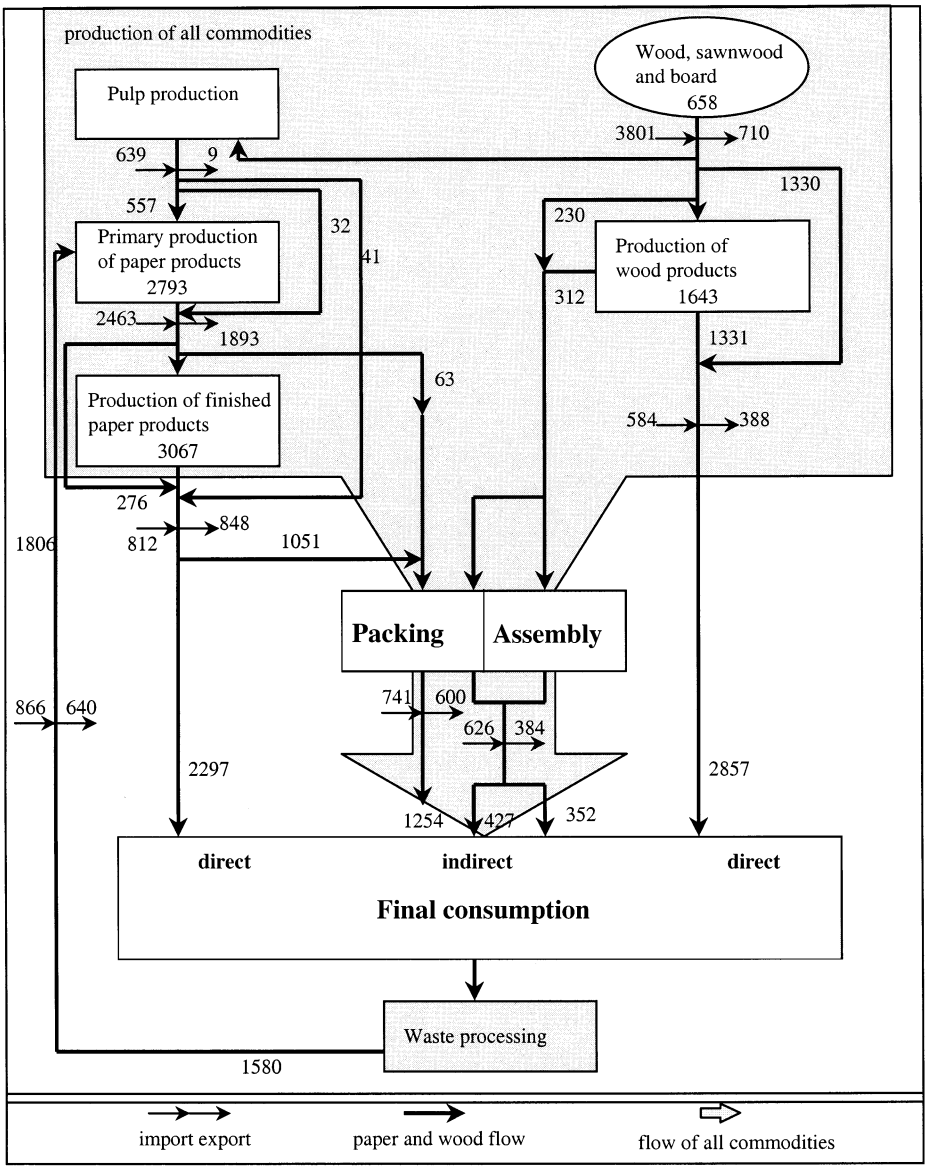


Fig. 3. Schematic presentation of results of STREAMS-calculations for the paper and wood flows in the Netherlands in 1990 (in kt).

complete view of the material flow, adequate information about the waste streams is required. In addition, no data are available for recycling streams unless there is an economic value related to it, like recovered paper. If a material flow can not be traced in the supply and use tables, other information sources must be used in order to complete the material flow analysis. This process may lead to problems as other data sources often use other definitions to describe products and industries.

Statistics Netherlands monitors only companies that employ more than 10 employees. Extrapolation methods are used to estimate the total figures for a certain sector. Since the wood industry in The Netherlands consists of many small companies, errors may be introduced in the supply and use tables.

A second shortcoming is that the methodology is not very suitable for creating a mass balance of the material flows as done in Ayres et al. (1989) because not enough insight in the production processes, waste flows and waste treatment is generated [11]. Joosten et al. (1998) try to solve this problem by calculating all plastic products back to their primary plastics content [5]. In the analysis of paper and wood flows, we decided not to do these calculations for two reasons: firstly, it would introduce more uncertainties because an average primary material content for different products is assumed. Secondly, the primary material content of the different products can be added later without too much trouble if more research has been done towards the amount of process waste and additives needed for manufacturing the products.

The reliability of the results is related to the uncertainties that are introduced with the different calculation steps. Introduction of uncertainties starts with the transformation of monetary data into physical data. Even though we followed the methodology of Statistics Netherlands, which is a very thorough method, uncertainties are definitely created. The main reasons are the estimated prices. Most prices are derived from the foreign trade statistics, which discern a wide variety of products. Due to publications of Statistics Netherlands we know exactly which products that are discerned in the foreign trade statistics are part of the categories stated in the supply and use tables [4]. However, it is hard to obtain a good indication of the material qualities that industries purchase and therefore it is difficult to calculate an exact price per demand category based on the foreign trade statistics.

For packaging material and product parts the STREAMS-calculations introduce other uncertainties as well. One of the first assumptions that have to be made in the STREAMS-method is whether a paper or wood product will be used as packaging material, product part or final product. Fortunately, for most paper and wood products it is quite obvious for which purposes they are used. For cardboard, however, this is not always the case. Cardboard can be used for cardboard boxes (packaging product) but also for advertisement purposes (like billboards). At first sight this may lead to large uncertainties. We reduced these uncertainties by treating service industries (where this problem occurs most) as final consumers of paper and wood products.

Other uncertainties are introduced when allocating the purchased packaging material and product components over the industrial output. This is not a statistical

calculation process but is largely influenced by the researchers knowledge of packaging technologies. In most cases it is quite obvious which commodities are packed and which are not. If this is not the case all purchased paper and wood products are divided over all commodities produced based on their relative output. This allocation method proved to be more functional than the allocation method in Joosten et al. (1999) [3], which is completely based on the relative outputs per industry, because with the latter method commodities for which it is obvious that no packaging material is used in the production still got a packaging share.

In the last steps of the calculations unavoidable errors are introduced because two assumptions were made. Firstly, we assume an average packaging or semi finished product intensity per commodity. Even though large differences in intensity are leveled out this way we follow this procedure because the use-table does not differentiate between the same commodities but produced by different industries. Therefore also the difference in packaging intensity cannot be taken into account. Secondly, we assume that commodities that are imported have the same packaging and semi-finished product intensity as domestically produced commodities. Even though this assumption is not very likely in the case of packaging we use this estimate because no information was available on the differences in packaging intensity of commodities between The Netherlands and other countries.

### *4.2. Comparison of results with other studies*

We will now evaluate the results of our analysis using the STREAMS method with FAO-statistics and several studies done in The Netherlands. The latter is needed because it is not possible to compare the final consumption data from our analysis with the FAO statistics. This is due to the fact that the FAO statistics do not discern final but only basic paper and wood products. In other words: the FAO determines the paper and wood flow at the level of the paper and board mills and the wood industries while most of our data is about products manufactured by industries like the paper converting, printing, publishing, wooden furniture and other wood products industries.

In Table 10 we compare our results at the level of the paper and board industry and the wood industry with FAO and PPI data [6,13]. The comparison is at an aggregated level because the sub-categories as stated by the FAO were not comparable to our results due to different definitions of the categories. Table 10 shows that our results are within an 11% range when compared to the FAO and PPI data.

Comparison of the results of our analysis using STREAMS with the results of other studies is difficult for various reasons. The first obstacle is a difference in aggregation. In most studies it is not clear which paper and wood products are part of a certain category. The second obstacle is the low consistency of most studies. Fraanje and Lafleur (1994) present a total picture of the paper and wood flow in the Netherlands based on numerous sources, showing that a lot of data about the consumption are not known and that estimates about total consumption therefore

Table 10
Comparison of production, foreign trade and apparent consumption data from our analysis with FAO and PPI statistics for The Netherlands in 1990 (kt)

| | Source | Production | Imports | Exports | App. consumption |
|---|---|---|---|---|---|
| Paper + paperboard | FAO | 2770 | 2420 | 2099 | 3091 |
| Basic paper and board | CBS | 2757 | 2498 | 1893 | 3362 |
| Deviation (%) | | −0.5 | 3.1 | −10.9 | 8.1 |
| Recovered paper | PPI | 1567 | 861 | 635 | 1820 |
| Recovered paper | CBS | 1580 | 866 | 640 | 1806 |
| Deviation (%) | | 0.8 | 0.6 | 0.8 | −0.8 |
| Basic wood products[a] | FAO | 1217 | 3983 | 949 | 4252 |
| Basic wood products | CBS | 1334 | 3698 | 897 | 4135 |
| Deviation (%) | | 8.8 | −7.7 | −5.7 | −2.8 |

[a] The FAO presents its wood data in cubic meters. For the comparison we used the densities as stated in FAO (1995) [12].

Table 11
Comparison of results of other studies with results of supply/use analysis

| Type, other studies | Amount (kt) | Type, supply/use analysis | Amount (kt) | Difference (%) |
|---|---|---|---|---|
| Cardboard waste, households | 379 | Cardboard use, households | 397 | 5 |
| Packaging paper and cardboard waste, households and service industries | 740 | Packaging paper and cardboard use households and service industries | 706 | 5 |
| Newspaper waste, households | 345 | Newspaper consumption, households | 315 | 9 |
| Furniture consumption, households | 372 | Furniture consumption, households | 368 | 1 |
| Wood board consumption, households | 278 | Wood board consumption, households | 290 | 4 |

may be on the low side[7] [14]. The third obstacle is related to the way the information is collected. Examples are the paper waste studies where the amount of recovered paper generated in the Netherlands is estimated [15]. Since not all paper products are purchased and converted into waste within the same year no direct comparison can be made with the paper consumption data of households resulting from the STREAMS analysis. For some paper products however, like newspapers and packaging paper, a reasonable comparison can be made.

[7] For example, Fraanje and Lafleur (1994) state that, based on literature, only 20% of the total wood consumption is traced back to the construction industries [15]. This low estimate is due to a lack of wood consumption data in the construction industry.

In Table 11 results of other studies are compared with results of our analysis. The first row shows a comparison between the cardboard consumption of households according to the STREAMS analysis and the amount of cardboard waste produced by households [15]. Fraanje and Lafleur (1994) [13] estimated this quantity based on sorting experiments done in 1989 and extrapolated this quantity with the production growth between 1989 and 1990. The next row shows a comparison of packaging paper and cardboard use by households and service industries as calculated with the STREAMS-method and waste data for the same paper categories by the same consumers based on Knol (1991) [15]. The last comparison for paper products is the consumption of newspapers by households resulting from our analysis with the newspaper waste by households in 1990 based on Nagelhout (1991) [15]. Table 11 shows that our results deviate between 5 and 9% with other studies. The lower rows show the comparison of the consumption of different wood products by households. The results of the supply/use analysis correspond well (within 1–4%) with Fraanje and Lafleur (1994) [13] who estimated these data based on production and foreign trade statistics and production data from the DIY-sector [14].

Even though just a small selection of the results is compared with other studies, these examples suggest that the methodology results in a representative picture of the actual situation. Furthermore the methodology offers advantages compared to other studies considering detail, consistency and type of information that can be read from the analysis i.e. final consumption, indirect consumption, aggregation per commodity, aggregation per final consumer etc.

### *4.3. Discussion of results*

The analysis of the paper and wood flow in The Netherlands showed that paper packaging is a substantial part of the total paper flow (about 35% of the total paper consumption). Wood packaging and wooden parts in products have a smaller share in the total wood flow (about 11 and 9%, respectively). A large part of the indirect consumption of paper (packaging) is imported with other products ($\approx 60\%$). For wood products this share is even larger ($\approx 80\%$).

The total final consumption of paper products is calculated at about 3600 kt. The apparent consumption of paper that results from our analysis is about 3400 kt. The difference between the apparent consumption and the final consumption is relatively small (about 5%). The reason for this small deviation is that the imports and exports of final paper products are about the same magnitude. The calculated final consumption of paper products is larger than the apparent consumption as stated by the FAO [13]. The difference is 13%.

For wood products the difference between final consumption (about 3900 kt) and apparent consumption (about 4300) is about 9%. The reason for this is that the imports of final wood products are substantially larger than the exports, about 600 and 400 kt, respectively. The difference with the apparent consumption as stated by the FAO is smaller (about 6%) [13].

For the paper flow we are able to calculate the recovery rate of paper because the supply and use tables contain recovered paper data. The recovery rate, the amount

of recovered paper that is collected in The Netherlands in 1990 divided by the amount of paper products that is consumed in The Netherlands in 1990, is calculated at 45%. Based on PPI (1997) statistics the recovery rate is be calculated at 51%. The difference in recovery rate is due to the use of final consumption figures in this study compared to the use of apparent consumption figures in the PPI statistics. This shows the value of generating better insights in the final consumption of economies.

The amount of recovered paper that is used by the paper industry amounts to 76% of the feedstock used. The large difference between the recovery rate and the recovered paper input is related to large imports of recovered paper and basic paper products in The Netherlands.

The calculations resulted in a good overview of the final consumers of the paper and wood products. Households are the major consumers of paper and wood products, 1400 and 1500 kt, respectively in 1990. Especially the amount of paper packaging is very large (700 kt) compared to the other final demand categories. The largest consumers of packaging wood are the industries (200 kt).

The consumption of food and tobacco products leads to the largest indirect consumption of packaging paper and packaging wood (600 and 100 kt, respectively in 1990) compared to the consumption of other final demand categories. Furthermore the consumption of metal products and machinery leads to a large consumption of packaging material made out of paper and wood (300 kt in total).

Based on the total final paper consumption in The Netherlands in 1990, the consumption per capita can be calculated at 237 kg per capita. This is substantially higher than the 204 kg per capita as stated by PPI (1997) [6]. We explain this difference by the fact that we calculated the final consumption of paper products including the indirect consumption of packaging material and that PPI (1997) makes calculations based on apparent consumption figures.

### *4.4. Application of STREAMS method*

Application of the STREAMS method results in data that are categorized according to the definitions compiled by Statistics Netherlands. These category definitions differ from the ones used in the international statistics. These different definitions make data comparisons difficult. We propose that more uniform definitions are used by the different statistical offices.

A shortcoming of the STREAMS method is that only little insight is created in waste flows. This is directly related to the fact that these flows are only recorded in the make and use tables when these flows are subject of trade and represent a monetary value. This shortcoming can only be improved if the focus of statistical offices will shift towards physical flows instead of monetary flows. By doing this also waste statistics may be incorporated in physical make and use tables.

The use of the STREAMS-method for analyzing material flows in other countries than The Netherlands or in future years depends on the quality and availability of statistics. First of all, disaggregated supply and use tables should be available. Secondly, detailed price statistics are needed. In our case, most prices were derived

from the foreign trade statistics. Recent developments within Statistics Netherlands resulted in foreign trade statistics where only monetary values are presented. Due to these developments, price calculations become very difficult. Furthermore, due to trade liberalization within the European Union future foreign trade statistics might be of a different quality. If these trends will continue, material flow analysis based on (national) statistics will become more difficult and less accurate.

## 5. Conclusions and recommendations

The paper and wood flows in The Netherlands in 1990 have been calculated using the STREAMS method. The method resulted in a better overview than existing methods, because: (i) a consistent overview of the material streams is obtained because one uniform source is used for the analysis; (ii) the results are more detailed than other methods; and (iii) insight is gained in the material flows that are not visible in statistics i.e. packaging materials and parts (attached to or incorporated in other products). Disadvantages are that the methodology requires some assumptions that are based on the researcher's knowledge of the subject and that it is elaborate (due to numerous price estimates and large numbers of matrix multiplication). Furthermore, case studies need to be performed to assess whether the methodology is also applicable to other countries than The Netherlands.

The application of the methodology to the paper and wood streams showed that the total final consumption of paper products in The Netherlands in 1990 was 3600 kt. The final consumption of wood products is calculated at 3900 kt. Paper packaging is a substantial part of the total paper flow (about 35% of the total paper flow). Wood packaging and wooden parts in products have a smaller share in the total wood flow (about 11 and 9%, respectively). A large part of the indirect consumption of paper (packaging) is imported with other products ($\approx 60\%$). For wood products this share is even larger ($\approx 80\%$). The results of the analysis also point out that the consumption of food and tobacco products and metal products/machinery leads to the largest indirect consumption of paper and wood packaging. Households consume most paper and wood products compared to other final demand categories. The construction industry is the second most important consumer of wood products and the other industries are the largest consumer of packaging wood. The paper consumption per capita in The Netherlands in 1990 is calculated at 237 kilograms. PPI (1997) calculated the consumption per capita in The Netherlands in 1990 at 204 kg per capita. This indicates that end-use calculations provide other insights in the paper and wood flow than apparent consumption calculations. This effect is also visible for the analysis of the recovery rate of paper. This study shows a recovery rate of 45% in The Netherlands in 1990 while PPI statistics suggest a recovery rate of 51%.

Trends are visible that statistical offices collect less physical data about material flows. We are concerned about these developments because it will make material flow analysis based on national statistics more difficult and almost certainly less accurate.

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